

Optical Flow in Driver Assistance Systems

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1 About the thesis

Motion perception is one of the most important attributes of the human brain. Visual motion perception consists in inferring speed and direction of elements in a scene based on visual inputs. Analogously, computer vision is assisted by motion cues in the scene. Motion detection in computer vision is useful in solving problems such as segmentation, depth from motion, structure from motion, compression, navigation and many others. These problems are common in several applications, for instance, video surveillance, robot navigation and advanced driver assistance systems (ADAS). One of the most widely used techniques for motion detection is the optical flow estimation. This research attempts to make optical flow suitable for the requirements and conditions of driving scenarios.

Traditional computer vision represents an image by the Cartesian co-ordinate system typically with uniform sampling in both x and y axes. Unlike computer vision, biological vision (human eye) has higher sampling at the center where it is gazing and reduced resolution at the surround. This phenomenon can be well defined through log-polar sampling and is generally called a space-variant representation. One of the major advantages of space-variant representations is reduction in the data to be processed. Since optical flow estimation is a very time consuming task, space-variant representation motivates us to enable faster / real-time ADAS applications which involve optical flow. Motivated by the advantage of the space-variant representation, the need of faster computation in ADAS domain has resulted in the proposal of a novel space-variant representation that we refer to as the Reverse Log-Polar representation. The proposed space-variant representation has the similar advantage of reduction in data and being more rich in information for ADAS.

In a driving scenario, a vehicle might be driven in a variety of roads, speeds, daylight conditions, seasons, environments (such as urban, highway, countryside). Thus, the situation while driving is unpredictable with added complexity, e.g., moving vehicles and pedestrians in the scene. Accuracy of the optical flow in any of such scenarios is expected to be good enough for reliability of ADAS. Having different algorithms for different scenarios is not a feasible option for real-time applications. Hence, there is a need for an optical flow algorithm that gives reasonable accuracy in all the scenarios. This motivates to tune the algorithm for different characteristics of a driving scene. There are no such previous studies in the literature. In this research, we study the influence of different speeds and different road textures on optical flow accuracy. For this analysis we choose an optical flow algorithm that uses polar representation of flow vectors. The formulation of this

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algorithm provides the advantage of having different regularization on different polar coordinates. In the current research we also show that such a representation makes sense on flow fields in driving scenarios. There exists no suitable dataset for the above mentioned analysis. Obtaining sequences of driving scenarios with exactly the same geometrical and textural scene but with different speeds and road textures is impossible unless done in a laboratory environment with limitations. This drives us to develop a virtual 3D urban scenario and to generate required driving sequences with corresponding ground-truth flow fields for the analysis. Thus we have developed a synthetic dataset of an urban scenario containing several sequences of different speeds and road textures with ground-truth data.

Having made attempts to reduce the amount of information to be processed and to analyze the influence of the driving scene characteristics on optical flow accuracy, further we have made an effort to use it for some of the ADAS applications. First, we propose a RANSAC based robust vanishing point estimation technique using dense optical flow. In turn, the horizon line is also estimated. This horizon line can be used to limit the searching space for pedestrian detection or any moving object detection in a road. Furthermore, we present an egomotion estimation application using the optical flow computed on space-variant represented images. It is shown by this application that optical flow on the proposed space-variant representation is more accurate for ADAS applications than that on the log-polar one.

In addition to all of the above efforts on optical flow and its applications, we have made an attempt to adapt an existing state of the art optical flow approach to driving scenarios. In a driving scenario, a scene may contain complexities such as large displacements, specularities, reflections etc. A typical optical flow formulation involves the gradient of flow components in the regularization part. For large variations such as large displacements, the Laplacian of flow components is used which notably improves the results. The experiment on a real dataset demonstrates the improvement in results.

In summary, this research contributes to the following topics:

- A novel space variant representation is proposed [2]. Unlike the traditional log-polar representation, it is suitable for ADAS applications.
- A synthetic urban driving scenario dataset with optical flow ground-truth is developed [3][4]. The dataset consists of sequences of different speeds, different road textures, and with added complexities of camera motions and moving vehicles in the scene.
- It is demonstrated that in driving scenarios the polar represented optical flow formulation exhibits statistical independence of the flow components upon which regularization can be varied independently.
- Analysis of variations of optical flow accuracy for different speeds and road textures is performed and tuning weights of regularization to improve the results are suggested [1].
- A few applications of optical flow in ADAS such as horizon line estimation and egomotion estimation are presented.
- A modification to the regularization term, based on the use of the Laplacian derivatives of the flow components, is proposed; and it is shown that the results are notably better in ADAS scenarios.

References

- [1] N. Onkarappa and A. D. Sappa, "Speed and texture: an empirical study on optical flow accuracy in ADAS scenarios", *IEEE Transactions on Intelligent Transportation Systems* 15(1):136-147, 2014.
- [2] N. Onkarappa and A. D. Sappa, "A Novel Space Variant Image Representation", *Journal of Mathematical Imaging and Vision* 47(1-2):48-59, 2013.
- [3] N. Onkarappa and A. D. Sappa, "Synthetic sequences and ground-truth flow field generation for algorithm validation", *Multimedia Tools and Applications* doi: 10.1007/s11042-013-1771-7.
- [4] www.cvc.uab.es/adas/site/?q=node/59